WIRELESS DATA COMMUNICATION METHOD VIA ULTRA-WIDE BAND ENCODED DATA SIGNALS, AND RECEIVER DEVICE FOR IMPLEMENTING THE SAME

The present invention concerns a method for the wireless communication of data between a transmitter device and a receiver device. The transmitter device transmits ultra-wide band encoded data signals via a first wide band antenna, and the receiver device receives direct and/or multiple path encoded data signals via a second wide band antenna from the transmitter device. The transmitted data is defined by one or several successive sequences of N pulses where N is an integer number greater than 1. The arrangement of the N pulses of each sequence represents data encoding relating to the transmitter device, i.e. personalising the transmitter device.

The invention also concerns the receiver device for implementing the method.

In the present description, “data” means textual information, which includes one or several symbols or characters, audiovisual information, synchronisation information or positioning information or other information. The data transmitted in the data signals is defined by one or several very short pulse sequences whose encoding can be defined by the time difference between each pulse.

Ultra-wide band data transmission technology is achieved using data signals which include a series of very short pulses without using a carrier frequency. The width of these pulses can be less than 1 ns. Since the data signal pulses are very short in the time domain, when converting into the frequency domain, this leads to an ultra-wide band spectrum, which defines UWB technology. The frequency spectrum can range from 500 MHz to several GHz. The frequency bandwidth is generally greater than 25% in relation to the central frequency for ultra-wide band technology.

Data transmission via ultra-wide band technology normally occurs from a short distance with low transmitted pulse power. This is generally due to the fact that the frequency spectrum is shared with narrow band transmission devices. This means that a single pulse is generally received with a lower power level than the noise level. Thus, it is often necessary to use more than one energy pulse to transmit a single symbol or character in order for it to be recognised by the receiver device.

For the transmission of encoded data signals which includes one or more successive sequences of N very short pulses, the pulses can be of different shapes provided that their width is generally less than 1 ns. They may be, for example, Gaussian shape pulses with one or two polarities or alternations.

Since several ultra-wide band (UWB) transmitter and receiver devices can be located in proximity in the same space for transmitting data signals, as a rule the transmitted data signal sequence encoding is personalised for the transmitter device.

In this way, the receiver device can recognise the encoded signals from a particular transmitter device. In addition, all of the codes used for encoding data are, as a rule, orthogonal, which means that when they are correlated with each other, the correlation result gives a value close to 0.

Usually, the data transmitted in pulse sequence signals can be encoded for example by pulse position modulation (PPM). The time difference between each pulse, and the instant that the first pulse of each sequence appears can thus define the desired encoding for data communication. In order to do this, the pulses of each sequence are transmitted at a pulse repetition frequency (PRF), which can be greater for example than 10 MHz. Each of the pulses is thus transmitted in a repetition window of a determined length which can be for example 20 ns or more. As a function of the desired time encoding, the pulse may be lead or lag in relation to a determined theoretical transmission position so as to be able to code for example a "0" or a "1".

When a pulse sequence encoded signal transmission is carried out as above-mentioned, it is necessary that the pulses can be detected as a function of their position via a PPM modulation for the signal reception in the receiver device. This generally requires a high time coherence in transmitter and receiver devices for the detection of transmitted data.

The encoded data signals, which are transmitted by the transmitter device, can be reflected or refracted by various obstacles before being picked up by the receiver device. Consequently, several time shifted encoded signals, i.e. direct and/or multiple path signals, which include identical data, can be picked up by the receiver device.

Several techniques for demodulating the information contained in encoded data signals received by a conventional receiver device have already been proposed in the past. One of these known techniques consists in correlating encoded data signals picked up and shaped in the receiver device with a reference signal lead replica and lag replica. The correlated phase lead and phase lag signals are then integrated, and a code adjustment is made of each replica in a code control loop until the level of the integrated phase lead and phase lag signals is identical. However, if all of the multiple path signals have to be detected, several correlation stages are used in parallel. Consequently, the electric power consumption of the receiver device is large, and many electronic components are necessary for processing signals in the receiver device, which constitutes a major drawback.

US Patent Application No. 2003/0095609 discloses a UWB method and apparatus for receiving several time spaced signals. The ultra-wide band signals are received by an antenna of the apparatus in order to be correlated in a correlator with a replica generated via a precision time generator. In order to obtain a replica like the

encoding of the signals picked up by the antenna, the generator is clocked by a clock signal of a time base, and receives a code control signal from a code source. At the correlator output, the intermediate signals undergo temporal integration prior to demodulation and summation of the pulses in order to retrieve information from the received ultra-wide band signals.

One drawback of this apparatus is that a correlation operation has to be carried out prior to demodulating and adding the pulses of the intermediate signals to retrieve information. Moreover, the shape of the pulses must be known, and only the direct path signals or one of the multiple path signals can be detected with this apparatus, which is a drawback.

US Patent No. 6, 483,461 discloses an ultra-wide band signal reception apparatus, which includes the same elements as the apparatus in US Patent Application No. 2003/0095609 so as to be used for positioning purposes. Consequently, the same drawbacks are noted as with the reception apparatus of the preceding Patent Application.

US Patent Application No. 2003/0058963 discloses a method and a device for receiving ultra-wide band type pulse signals. The signals include a heading frame for seeking synchronisation in the reception device. In order to do this, the ultra-wide band signals are received by an antenna of the device in order first of all to be compared to a threshold voltage in a comparator. At the output of the comparator, intermediate signals represent the sign of the received signal in relation to a threshold voltage. These intermediate signals are then sampled in sampling means, and sliding correlation is performed on a final set of samples using a reference replica to remove noise. This set of samples results of an addition of several groups of sampled signal samples. Each group of samples represents one of the pulses of the ultra-wide band signals, whose the temporal width of each group is equal to or greater than the reverse of a pulse repetition frequency of the ultra-wide band signals.

One drawback of such a device is that the information relative to the sign of pulses of ultra-wide band signals has to be exclusively used. Furthermore, the synchronisation check has to be carried out by using information after correlation operation. A pulse energy maximization in the set of samples from the addition directly is not carried out, which is another drawback.

US Patent Application No. 2003/0198308 discloses a UWB time reference delay-hopped TR/DH communication system. The system reception device includes several pulse pair correlators operating in parallel to perform auto-correlation of the signals received by an antenna, and an analogue-digital converter at the output of

each correlator. The information is subsequently demodulated using a known CDMA technique.

One drawback of this device is that it is necessary to carry out correlation operations as soon as the UWB signals are received, which complicates the manufacture of this device in the same way as for US Patent Application No 2003/0095609. Further, the communication system is limited to double pulse signals.

US Patent Application No. 2003/0002347 discloses an ultra-wide band signal reception apparatus, which includes the same elements as the apparatus of US Patent Application No. 2003/0198308 so as to be used for positioning purposes. Consequently, the same drawbacks are observed as with the reception apparatus of the preceding Patent Application.

It is thus a main object of the invention to overcome the drawbacks of the prior art by providing a wireless data communication method via ultra-wide band encoded data signals which is able to process simply all of the encoded direct path and/or multiple path signals picked up by the receiver device.

It is another object of the invention to provide a wireless data communication method via encoded ultra-wide band data signals for maximising the amplitude of the data pulses in relation to the noise picked up by the receiver device.

The invention therefore concerns an aforecited method which is characterized in that the N pulses of a pulse sequence of encoded direct path and/or multiple path data signals received by the receiver device are each processed in one of N corresponding temporal reception windows, each of the N temporal reception windows being positioned in time as a function of a known theoretical arrangement of the N pulses of the signals transmitted by the transmitter device, and in that an operation of adding the N windows is performed in the receiver device such that the added pulse amplitude level is higher than noise amplitude level picked up by the receiver device.

One advantage of the communication method according to the invention is that most of the pulses of the direct path and/or multiple path signals received from each temporal window can be added coherently, since each of the N temporal reception windows is positioned in time in accordance with a known placing of the N encoded data signal pulses transmitted by the transmitter device. Even if the direct path signals cannot be picked up by the receiver device because of an obstacle on the signal path, it is possible to add coherently the pulses of each corresponding window from the multiple path encoded signals.

This coherent addition of N windows does not occur in conventional communication systems such as those disclosed in US Patent Applications Nos. 2003/0095609 and 2003/0198308.

Each window can be chosen with sufficient width to pick up each of the N pulses of all of the signals picked up by the receiver device. This width, which is the same for all the temporal windows, can be adjusted as a function of the propagation features of the transmission channel, and during the time and frequency search phase for received signal data acquisition. The width of each window may be for example 20 or 50 ns, and each window is, as a rule, centred on a theoretic reference position relative to the direct path signal pulses.

The position of the start of each window corresponds to the position of the encoded data signal sequence pulses for carrying out coherent addition of the pulses of each window. With this coherent addition of the temporal window pulses, the added pulse amplitude level becomes higher than the noise level if the receiver device is properly synchronised in time and frequency in relation to the transmitter device. After this temporal window addition step, data demodulation can be carried out in a signal processing unit of the receiver device.

The window addition can be achieved analogically prior to analogue-digital conversion of the data signals, or digitally after analogue-digital conversion. In order to reduce the electric power consumption of the receiver device, signal sampling can only be carried out in an analogue-digital conversion stage during time intervals that are identical to the duration of the temporal windows.

Because of the temporal window addition, the noise signal amplitude level picked up by the receiver device is greatly reduced, in relation to the added pulse level. This is due to the fact that the voltage polarity of the noise signals in the time interval of each window is not precisely defined, unlike the voltage polarity of the data signal pulses.

Preferably, the data is encoded by time modulation of the pulses of each sequence as indicated hereinbefore. However, one could also envisage encoding the data by pulse polarity or phase modulation or by a combination of pulse time and polarity or phase modulation. In the case of pulse polarity modulation, each window, which includes one or several pulses, is multiplied by –1 for pulses of negative polarity and by +1 for pulses of positive polarity so as to be able subsequently to add the pulses of all the windows in a coherent manner.

Another advantage of the communication method according to the invention is that the clock or sampling signals of the receiver device can be frequency adjusted owing to the result of the temporal window addition. The clock or sampling signal

frequency is adjusted to the clock signal frequency of the transmitter device by a signal processing unit of the receiver device. This frequency adjustment can be made at any time when, for example, an alteration to the position of the added pulses in a final temporal window is observed, or when the added pulse amplitude level decreases.

In order to carry out this adjustment, the data signals transmitted by the transmitter device can include a synchronisation frame. This synchronisation frame includes several successive sequences of N personalised pulses to the transmitter device. Thus, since the receiver device knows the position of the pulses of each of the sequences, it can carry out a two dimensional time and frequency search to find the start of transmission and the frequency gap.

Owing to the communication method according to the invention, it is possible to choose and track the sampling or clock signal frequency in order to maximise the added pulse amplitude peak whether the pulses are direct or multiple path signal pulses.

Another advantage of the communication method according to the invention is that it can be used for positioning purposes. In order to do this, at least two transmitter devices, or even three transmitter devices are generally required to transmit encoded data signals. This enables the receiver device to calculate the positioning coordinates as a function of the first encoded signal time of arrival as described hereinafter. For a positioning operation, the number N of pulses per transmitted data sequence can be for example equal to 1024 with a pulse width of for example 0.5 ns.

Another advantage of the communication method according to the invention is that the noise level picked up can be estimated in the signal processing unit of the receiver device. In order to do this, several maximum signal absolute value amplitudes are calculated successively or in parallel in one or several temporal sub-windows in the signal processing unit of the receiver device. These sub-windows are shifted by specified time intervals from the start of the temporal window at the end of said temporal window. An estimation of the noise amplitude level is carried out by selecting the minimum amplitude value from all the calculated amplitude values. This estimation can be carried out before or after the temporal window addition operation.

Another advantage of the communication method according to the invention is that it enables the time of arrival of the first direct path and/or multiple encoded data signals to be calculated. In the case where the direct path signals are not picked up by the receiver device, the first multiple path signals are processed. This time of arrival estimation operation consists first of all in calculating a positive signal envelope for each temporal window or the final temporal window. Afterwards, minimum and

maximum points of the envelope are determined and a central point is calculated, one of whose functions, which may be tangent or linear, allows estimating the rising edge of the envelope.

The invention also concerns a receiver device for implementing the wireless data communication method wherein all of the direct path and/or multiple path encoded signal pulses picked up can be processed simply.

Therefore, the receiver device for implementing the communication method, which includes a second oscillator stage delivering at least a second clock signal at a second defined frequency, a second signal processing unit connected to the second oscillator stage, and an analogue-digital conversion stage for the encoded data signals received by the second wide band antenna, is characterized in that the signal processing unit includes temporal window adding means for coherently adding the pulses of each of the N temporal windows.

The objects, advantages and features of the wireless data communication method via ultra-wide band signals, and of the receiver device for the implementation thereof will appear more clearly in the following description of embodiments of the invention with reference to the annexed drawings, in which:

- Figure 1a shows schematically a data communication system for implementing the communication method according to the invention, wherein the temporal windows are added digitally in a receiver device,

- Figure 1b shows schematically a data communication system for implementing the communication method according to the invention, wherein the temporal windows are added analogically in a receiver device,

- Figure 2 shows schematically how the signals of the N temporal windows are added in a receiver device for the communication method according to the invention,

- Figures 3a to 3d show graphs showing a temporal data encoding modulation, polarity data encoding modulation, temporal and polarity data encoding modulation, and amplitude encoding modulation of the transmitted data of the communication method according to the invention,

- Figure 4 shows in a simplified manner the encoded data signals starting with a synchronisation frame for the communication method according to the invention,

- Figure 5 shows signal graphs in the transmitter device and in the receiver device in the case of time and frequency synchronisation of the clock signals of the two devices, in the case of a frequency gap between the clock signals and in the case of non temporal synchronisation of the windows of the communication method according to the invention,

- Figures 6a and 6b show one embodiment of an analogue-digital conversion stage of the receiver device, and clocking signals of the conversion stage for implementing the communication method according to the invention,

- Figure 7 shows a signal graph of one temporal window of the receiver device of the steps for estimating the noise level picked up of the communication method according to the invention,

- Figure 8 shows a graph of one part of a temporal window of the receiver device of the steps for calculating the positive signal envelope of the temporal window of the communication method according to the invention, and

- Figure 9 shows a graph of one part of a temporal window of the receiver device of the steps for calculating the time of arrival of the first encoded direct path or multiple path data signals of the communication method according to the invention.

In the following description, those elements of the wireless data communication system via ultra-wide band encoded data signals used for implementing the communication method, which are well known to those skilled in the art, will not be explained in detail.

Figures 1a and 1b shows schematically a communication system 1 for implementing the wireless data communication method via ultra-wide band encoded data signals S_D. Communication system 1 includes at least one transmitter device 2 which transmits encoded data signals S_D via a first wide band antenna 27 and a receiver device 3 which receives direct and/or multiple path encoded data signals via a second wide band antenna 37.

As explained hereinafter, particularly with reference to Figure 2, the direct path and/or multiple pulses received by receiver device 3 and corresponding to transmission of one of the N encoded data signal pulses are processed or selected in one of the N corresponding temporal windows in receiver device 3. Since each temporal window is positioned chronologically as a function of the known position of each pulse of the transmitted encoded data signals S_D, an addition of the temporal windows is performed in order to add coherently the pulses of each window.

Generally, transmitter device 2 includes a stage oscillator 21 for providing a clock signal CLK_e, whose frequency depends upon a quartz resonator 22, a signal processing unit 23 clocked by the clock signal, and a pulse shaping unit 24 connected to signal processing unit 23. Given the use of a stage oscillator 21 with a quartz 22, the frequency of clock signals CLK_e can preferably be multiplied M times in signal processing unit 23. This multiplication by M of the frequency of clock signals CLK_e is obtained conventionally using lag gates that are not shown, and a combination of the clocking pulses at output of the lag gates.

In signal processing unit 23, the useful frequency for generating data pulses may be greater than or equal to 1 GHz. This requires the use of at least 4 lag gates shifted by a quarter period in relation to a period of clock signal CLK_e at a frequency of the order of 250 MHz.

For UWB encoded data signal transmission, processing unit 23 of transmitter device 2 has to provide, to pulse shaping unit 24, one or several sequences of N successive pulses of positive or negative voltage or current polarity. Each pulse of the sequences is generated in a time interval corresponding to the reverse of a pulse repetition frequency. For UWB data signals, this pulse repetition frequency (PRF) can be higher than or equal to 10 MHz.

The way in which the data is encoded in sequences of N pulses in signal processing unit 23 of transmitter device 2 must, on the one hand, differentiate each symbol or character to be transmitted and, on the other hand, personalise the transmitter device. A close receiver device 3 can thus recognise where the received data signals have come from, since the various codes used for personalising the transmitter devices are orthogonal.

Pulse shaping unit 24 receives the data in the form of one or more sequences of N pulses to be transmitted by the first UWB antenna 27 of signal processing unit 23. These encoded data pulses in processing unit 23 are amplified in an amplifier 25 of pulse shaping unit 24, and filtered in a conventional bandpass filter 26 prior to being transmitted by first UWB antenna 27. Generally, the shape of the energy pulses of data signals S_D transmitted by first UWB antenna 27 is obtained by derivation of the shaped pulses, due to an antenna current switch. The transmitted pulses must be Gaussian shaped with one or two alternations, or of another shape.

Figures 3a to 3d show the way in which the data is encoded, such as one or more characters or symbols, by one or more sequences of N pulses in the data signals.

The data can be encoded by temporal modulation of the pulses of each sequence, as shown in Figure 3a. This is called Pulse Position Modulation (PPM). The pulses presented are Gaussian shaped with two alternations. Of course, the pulse shape can also be Gaussian with one positive or negative alternation, or of various other shapes.

In Figure 3a, each character C1 and C2 is defined by N pulses, each pulse of which is of smaller length than 1 ns, in a sequence repetition period $T_{rép}$. Each pulse is generated by temporal interval 1/PRF corresponding to the reverse of the pulse repetition frequency PRF as described hereinbefore. The temporal position of each pulse in the temporal interval is specific to the character to be encoded. Moreover, the

gap between each pulse of the sequence of N pulses is preferably pseudo-random to personalise the transmitter device. With this arrangement of N pulses per sequence repetition period $T_{rép}$, the character or symbol C2 differs from character or symbol C1 only by a temporal difference dt of each of the N pulses generated. Of course, for other characters or symbols to be transmitted, the temporal difference dt is different each time.

The sequence repetition time $T_{rép}$ can be for example 0.1 ms with 1024 pulses per sequence, or 10 μs with 256 pulses per sequence.

The data can also be encoded by polarity or phase modulation of the pulses generated by the signal processing unit of the transmitter device as shown in Figure 3b.

In this Figure 3b, it will be noted that the identical temporal difference between each pulse is equal to a period repetition value 1/PRF. Conversely, the pulse polarity, particularly, the phase, is an encoding feature that personalises the transmitter device, as is the character or symbol D1 or D2 to be transmitted in the data signals.

The positive polarity or zero phase of double alternation pulses can define a +1 state, whereas negative polarity or 180° phase of double alternation pulses can define a –1 state. Since the shape of the pulses shown in Figure 3b is Gaussian with two alternations, the difference between a +1 state and a –1 state is observed via a 180° phase shift of the pulse. However, one could very well have imagined a Gaussian shape with positive alternation to define a +1 pulse state, or a negative alternation to define a –1 pulse state.

In Figure 3c, the data is encoded by a combination of temporal and polarity modulation of the pulses. The N pulses of a sequence for defining the character or symbol E1 or E2 are presented with a simple alternation. Each pulse can be of positive or negative polarity. However, the character or symbol E2 differs from character or symbol E1 via a temporal gap dt of each generated pulse. It should be noted that the polarity of each 1 alternation pulse of each character could also be different.

Finally, Figure 3d shows data encoding via amplitude modulation of the simple positive alternation pulses. The amplitude of a pulse below a determined amplitude threshold defines a 0, whereas the amplitude of a pulse above a determined threshold defines a 1. In the case of pulse amplitude modulation, the identical temporal gap between each pulse is equal to a pulse repetition frequency value 1/PRF. The character or symbol F1 differs from character or symbol F2 by a sequence of N pulses of different amplitude.

It should be noted that pulse amplitude modulation is not a robust method. Moreover, it is difficult to implement in UWB technology, which means that preferably, the data is encoded in accordance with one of the modulation methods shown in Figures 3a to 3c, or a combination of these modulation methods.

For the reception of direct path and/or multiple path encoded data signals S_D, receiver device 3 includes first of all a second wide band antenna 37. This antenna 37 provides signals, which are derived on the basis of the picked up encoded data signals, to a low noise amplifier (LNA) 36, fitted with a band pass filter. After this LNA 36, an automatic gain control amplifier (AGC) 35 can be provided, whose amplification factor A_C is controlled by control means 43 of a signal processing unit 33. Amplifier 35 provides amplified intermediate signals S_{INT} to an analogue-digital conversion stage 34 responsible for the digital conversion of the analogue signals.

Receiver device 3 further includes a stage oscillator 31 for supplying a clock signal CLK_r, whose frequency depends upon a quartz resonator 32, and a signal processing unit 33 clocked by clock signal CLK_r. Clock signals CLK_r are provided in particular to the signal processing unit control means 33.

Given the use of a stage oscillator 31 with a quartz 32, control means 43 are responsible for multiplying clock frequency CLK_r by a factor n as for the transmitter device described hereinbefore. On the basis of the clock signals CLKr, control means 43 provide in particular clocking signals CLK_{1-n} to analogue-digital conversion stage 34 for sampling operations. This conversion stage 34 will be described hereinafter with reference to Figures 6a and 6b.

It should be noted that in order to reduce the electrical power consumption of the receiver device, one could envisage only sampling the intermediate signals during periods identical to the temporal width of each window.

According to a first embodiment of receiver device 3 of Figure 1a, signal processing unit 33 includes in addition to control means 43, digital window addition means 41 for receiving sampled signals S_{NUM} from the analogue-digital conversion stage 34, data demodulation means 42 and time of arrival estimation means 44. Means 42 and 44 are both connected to the output of digital window addition means 41 for receiving signals from a final addition window W_S.

In order to control the operations of signal processing means 33, control means 43 first of all provide control signal C_{FN} to digital window addition means 41. These control signals C_{FN} adjust the temporisation of the temporal selection windows of parts of the digital signals, i.e. the placing of the first of the N windows in time.

In order to arrange the temporal windows, a two dimensional time and frequency search must therefore be carried out. This search will provide proper

synchronisation and a clock frequency of oscillator stage 31 proportionally adapted to the clock frequency of oscillator stage 21, which is the basis of the generation of the transmitted encoded data signal pulses. Thus, control means 43 can directly adjust the frequency of clock signals CLK_r by control signals C_H. These control signals C_H can adapt a resistive or capacitive value of a network of well known resistors or capacitors of oscillator stage 31.

Another frequency search method consists in using control signals C_{FN} to alter the pulse time or repetition frequency scale of the N windows to be added of the digital window addition means 41. This means performing a re-sampling operation in signal processing unit 33 of receiver device 3 with a different re-sampling frequency from the sampling frequency of analogue-digital conversion stage AN 34. The re-sampling frequency generated by control means 43 may be much higher so as to increase precision particularly for positioning.

Once the window addition operation has been performed in digital window addition means 41, the control means supply control signals C_D to the data demodulation means 42. These data demodulation means are able to provide data only if the N pulses of a temporal window sequence have been coherently added.

In order to recognise the character(s) or symbol(s) transmitted in the encoded data signals, signals W_S of the final window must present one or several pulses to demodulation means 42 whose amplitude is higher than a determined threshold and at the noise level picked up by receiver device 3. In this way, it is possible to determine the character(s) or symbol(s) particularly by the position of the pulses in the final window for PPM type modulation.

It should be noted that the maximum amplitude pulse of the final window is not necessarily due to the N added pulses of the direct path signals, since it is possible for obstacles on the path of the encoded data signals, to attenuate the amplitude of each direct path signal pulse or to prevent reception of such signals. However, since the N pulses of all the direct or multiple path encoded data signals have each to be processed in one of the N width-adapted temporal windows, it is possible to provide final window signals W_S to demodulation means 42 in which at lest one maximum pulse results from multiple path signals.

In order to estimate the noise level and time of arrival of the pulses of the first direct or multiple path encoded data signals, control means 43 provide control signals C_E to time of arrival estimation means 44 so that time of arrival data TOA is provided. These time of arrival estimation means are explained hereinafter with reference to Figures 7 to 9.

According to a second embodiment of the receiver device presented in Figure 1b, the essential difference in relation to the first embodiment of Figure 1a is that the window addition occurs in analogue window addition means 45. These means 45 can be outside signal processing means 33 or incorporated therein. The analogue window addition means 45 can be inserted between amplifier 36 and amplifier 35. However, means 45 can also be placed after amplifier 35 and before analogue-digital conversion stage 34.

Conventionally, in order to add up all the temporal windows analogically, a number N-1 of temporisation gates are used, not shown, whose time period is adjusted to the position of each of the desired N windows. The encoded data signals received by antenna 37 pass through each of these gates so as to be able to add up in proper synchronism, for a time period equivalent to the width of each window, the output signals of each temporisation gate and the input signals of the first of said gates. The signals resulting from this addition are then amplified by amplifier 35 and sampled by conversion stage 34.

Analogue-digital conversion stage 34 provides digital signals S_{NUM} matching the sampling of signals from the final addition window of analogue window addition means 45. These digital signals S_{NUM} are directly processed by demodulation means 42 and time of arrival estimation means 44.

Figure 2 shows the temporal window addition operation which is a main feature of the data communication method whether the addition is of analogue or digital signals.

The encoded data signals, which are picked up by the second antenna of the receiver device, include noise in addition to the pulses of each sequence defining the data to be demodulated. This noise is represented in Figure 2 by dotted lines to distinguish it from the encoded data signal pulses. It can be seen that in each window FEN_1 to FEN_N, direct and multiple path signal pulses are picked up by the receiver device, but with a lower amplitude level than the noise level.

The N windows, which contain the pulses of all the picked up encoded data signals, originating from a specific transmitter device, are arranged in accordance with a time arrangement determined as a function of the known theoretical position of each direct path encoded data signal pulse. The width of each window T_W is adapted so as to be able to detect the pulses of several direct and multiple path encoded data signals bearing the same data, which is one advantage of the present invention.

Each temporal window can have a width comprised between 20 and 50 ns for example, and starts before the appearance of each pulse of the direct path signals. However, this width may be smaller while picking up at last one of the multiple path

signals in addition to the direct path signals, or also larger for example of the order of 100 ns in the case of positioning.

In a positioning or text or synchronisation data communication system, it is generally advantageous for the width of the temporal windows to be larger during the temporal synchronisation search. This enables direct and/or multiple path signals to be detected which may be partially received with a lot of lag or lead on the theoretic desired position.

When temporal synchronisation is found and the clock signal frequency of the transmitter and receiver devices has been properly adjusted, each pulse of a data sequence is properly located in each temporal window. Consequently, when all of the temporal windows FEN1 to FEN are added up by at least one adder 51, all of the pulses of sequences of all the signals picked up by the receiver device are added up coherently to maximize the pulse amplitude level in relation to the noise level. Since the noise signal voltage polarity is not precisely defined in the time interval of each window, unlike the voltage polarity of the data signal pulses, after the addition operation the noise amplitude level is lower than the pulse amplitude level.

In order to obtain coherent addition of the pulses of each window, there must be proper synchronisation between the transmitter device and the receiver device. In order to do this before transmitting various characters or symbols in the data signals, one may wish to transmit a synchronisation frame at the start as shown symbolically in Figure 4. This synchronisation frame is composed of one or several successive sequences of N pulses. This leaves time for the receiver device to adjust the placing of the windows as a function of the position of each pulse of the sequences. Moreover, this leaves time for synchronising the frequency of the second oscillator stage 31 with first oscillator stage 21, or synchronising the re-sampling frequency of digital window addition means 41.

In order to understand the importance of having proper synchronisation between the transmitter device and the receiver device so as to be able to demodulate the received encoded signal data, reference can be made to various signals shown in Figure 5. Signals A to C are transmitter device signals, whereas signals D to I are receiver device signals. In this Figure 5, the number N of pulses is chosen to be equal to 5 which matches a processing gain PG of the order of 7 dB after the temporal window addition operation in the receiver device.

This processing gain can be calculated using the formula $PG = 10 \cdot \log N$ [dB], which means that if a larger gain is desired, each sequence, which defines one or several characters, must include a large number N of pulses. Of course, with a larger number of pulses per sequence, it is inevitable that data demodulation will slow down,

but this may be tolerated depending upon the type of data to be transmitted. For example, with a number N equal to 200, the processing gain will be of the order of 23 dB, and with a number N equal to 1024, the processing gain will be of the order of 30 dB.

Signals A are reference clock signals with a frequency f_0 which are used for clocking data modulation in the processing unit of the transmitter device.

Signals B are signals leaving the processing unit of the transmitter device which include one rectangular pulse per pulse repetition period 1/PRF. These signals B are trigger signals for the pulse shaping unit of the transmitter device.

Signals C are encoded data signals transmitted by the wide band antenna of the transmitter device. The data in these encoded signals are defined by double alternation pulses of smaller width than 1 ns.

Signals D are signals picked up by the wide band antenna of the receiver device. It will be noted that these signals can contain direct path and/or multiple path pulses, which can have a different shape from the pulses transmitted after the wide band antenna of the receiver device. In practice, a drift can be observed in the encoded signal pulses.

Signals E are clocking signals for sampling the analogue signals in the analogue-digital conversion stage of the receiver device. The sampling frequency f_s of signals E is identical to the frequency f_s of the reference clock signals of the transmitter device.

Signals F are clocking signals for sampling the analogue signals in the analogue-digital conversion stage of the receiver device, whose sampling frequency f_s has a frequency drift df relative to frequency f. This frequency has to be adjusted in the receiver device during the two dimensional time and frequency search phase.

Signals G are temporal windows of samples of selected parts of the data signals where the time between each start of a window exactly matches the time between each pulse of the data sequence. The sampling frequency f_s is adjusted to the frequency f_0 of the reference clock signals as shown by signals E. When the pulses of each of these windows of width T_W are coherently added up in the receiver device, it will be noted that the pulse amplitude level becomes higher than the noise level in final window G_F.

It should be noted that each temporal window receiving a part of the encoded data signals can be obtained, in the data processing unit of the receiver device, by a multiplication by 1 of the encoded signal parts to be selected, and by 0 of the parts to be removed.

Signals H are temporal windows of samples of selected data signal parts where a clock frequency drift is observed between the transmitter device and the receiver device by using sampling signals, like signals F. In this case, addition of the pulses of each window does not provide an added pulse amplitude level that is higher than the noise level in final window H_F.

Signals I are temporal windows of samples of selected data signal parts where the time between each start of a window exactly matches the time between each pulse of the data sequence, but without temporal synchronisation between the transmitter device and the receiver device. The sampling frequency f_s is however well adjusted to the reference clock frequency f_0 as shown by signals E. However, the start of the N windows is shifted time-wise, which means that no sequence pulse is picked up by the receiver device and gives a window addition without any pulses as shown in the final window I_F.

Since the receiver device knows the arrangement of the pulse sequences to be picked up, a first step consists in finding the start of each pulse sequence, either by time shifting in a serial manner or by searching in parallel at several different times. If the sampling frequency is not sufficiently close to the reference clock signal frequency of the transmitter device, this search can be repeated either in series, or in parallel with different sampling frequencies.

Once temporal synchronisation has been found, the sampling or re-sampling frequency can be adapted to the reference clock signal frequency of the transmitter device by controlling the pulse amplitude level in the final window until this amplitude level is maximised relative to the noise level.

At any time, the sampling or re-sampling frequency can be adapted by controlling any decrease in the pulse amplitude level in the final temporal window or by progressively moving pulses in said final window. The movement of added pulses in the final temporal window can be due to the Doppler effect if the transmitter device moves away from or towards the receiver device.

If the temporal window addition is performed analogically, as described hereinbefore and illustrated in Figure 1b, the sampling frequency will be frequency CLK_r, which controls the analogue window addition.

Figures 6a and 6b show an embodiment of the analogue-digital conversion stage of the receiver device, and the clocking signals of the stage converters.

The analogue-digital conversion stage includes a number n of converters AN 53 to 55 working in parallel. Each converter 53 to 55 is clocked by a clocking signals CLK_1, CLK_2 to CLK_n with an identical frequency to that of clock signals CLK_r generated by the oscillator stage. Each clocking signal CLK_1, CLK_2

to CLK_n is phase shifted by 360°/n for each converter 53 to 55. Consequently, the n phase shifted clocking signals allow sampling of intermediate analogue signals S_{INT} at an effective frequency f_e of n times the frequency of clock signals CLK_r.

Since the intermediate signal sampling is generally carried out at a frequency of 2 times the band width of the encoded data signals, for example at a frequency that may be equal to or higher than 2 GHz, one could envisage having 4 converters clocked by 4 clocking signals phase shifted in relation to each other by 90° as illustrated in Figure B. The frequency of clock signals CLK_r must thus be 4 times less than the effective sampling frequency f_e.

At each rising edge of the clocking signal, each converter 53 to 55 provides binary m bit signals S_{D1} to S_{Dn}, where m can have a value from 1 to 8. These binary signals S_{D1} to S_{Dn} are provided to series input and parallel output type combination means 56, which are responsible for combining all of the signals received from the converters in order to provide digital signals S_{NUM} for the signal processing unit of the receiver device.

Figures 7 to 9 show graphs of signals of a temporal window for estimating noise level, calculating the signal envelope of a window and the time of arrival of the data signals. These operations are carried out in the time of arrival estimation means 44 of signal processing means 33, shown in Figures 1a and 1b, under the control of control signals C_E generated by control means 43.

First of all, Figure 7 shows a method of estimating noise level A_N using a graph of the signals of one temporal window. This method is based on the fact that inside the temporal window observation interval, there is at least one temporal window portion of length T_N during which there is not energy belonging to the transmitted data sequence pulses. The estimated noise level A_N is lower than the maximum amplitude level A_P of the coherently added pulses.

In order to estimate noise level A_N, several absolute value maximum amplitude values A_i are calculated for signals $s_i(t)$, with i ranging from 0 to I, in temporal sub-windows of length T_N. The I+1 temporal sub-windows for calculating the amplitude values are time shifted in relation to each other by a determined time interval from the start of the temporal observation window to the end of said temporal window. For I+1 temporal windows to be calculated, the number of time intervals is I.

The absolute value noise amplitude level value A_N is equal to the minimum amplitude value among the A_i calculated values, or to the minimum value of the maximum of all the signals $s_i(t)$.

Figure 8 shows a method of calculating the positive envelope of the digitised temporal window signals over a part of said temporal window.

According to this method, firstly, all of the zero crossing positions p_i of the temporal window signals are determined, i.e. all the positions where sampling before and after p_i has an opposite sign. After this step, the coordinates (x_i, y_i) of the absolute value amplitude maximum is determined in each interval from p_i to p_{i+1}, with i ranging from 1 to I-1. Afterwards, the envelope is calculated using an interpolation algorithm which may be for example the piecewise cubic Hermite interpolation algorithm.

Finally, with reference to Figure 9, there is shown a method of estimating the time of arrival of the first data signals received by the receiver device. These first signals may be direct path signals or multiple path signals in the absence of any direct path.

For this estimation, an amplitude threshold th is first calculated which is based on the envelope amplitude peak A_P, and on the noise amplitude level estimation A_N described with reference to Figure 7. This threshold th may be calculated by the following formula: $th=5 \cdot A_N + A_P/25$.

Next, the rising edge of the envelope where threshold th is exceeded for the first time is estimated, by selecting a segment of the envelope shown in bold in Figure 9. An approximation of this segment with a given function is carried out so that it can be used to estimate the rising edge of the envelope. In order to do this, the maximum local point of the envelope is first estimated at the coordinates (x_M, y_M) which directly follow the point where the envelope passes above threshold th. The minimum local point of the envelope is also estimated at the coordinates (x_m, y_m) that precede the point where the envelope passes above threshold th.

After establishing these coordinates, the value y_h, which is equal to $0.5 \cdot (y_M+y_m)$ is calculated, which allows the corresponding coordinate x_h to be found. A time value $t_1 \leq \min(x_M - x_h, x_h - x_m)$ can then be selected.

After having selected time value t_1, a selection is made of a sample sequence from the envelope of length $2 \cdot t_1$ centred on coordinate x_h. Finally, an approximation is made of the selected sample segment of the envelope with a given function in a least square direction. This function may be of the linear type, which allows the rising edge of the envelope to be estimated based on this function. At point y=0 of this linear function, the time of arrival of the first signals can thus be determined.

From the description that has just been given, those skilled in the art can devise multiple variants of the data communication method via pulse signals without departing from the scope of the invention defined by the claims. The receiver device may not have an integrated filter low noise amplifier, since the wide band antenna of the receiver device can already fulfil the filtering functions. The receiver device can be arranged to act as the transmitter device, and the transmitter device may be arranged

to act as the receiver device so that a data exchange can occur.